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Lee et al.

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(54) **DISCHARGE CIRCUITS OF DISCHARGE PATHS FOR ELECTROMAGNETIC INTERFERENCE FILTERS**

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Primary Examiner — Scott Bauer

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H02H 9/04 (2006.01)
H02H 1/00 (2006.01)
H02H 9/00 (2006.01)

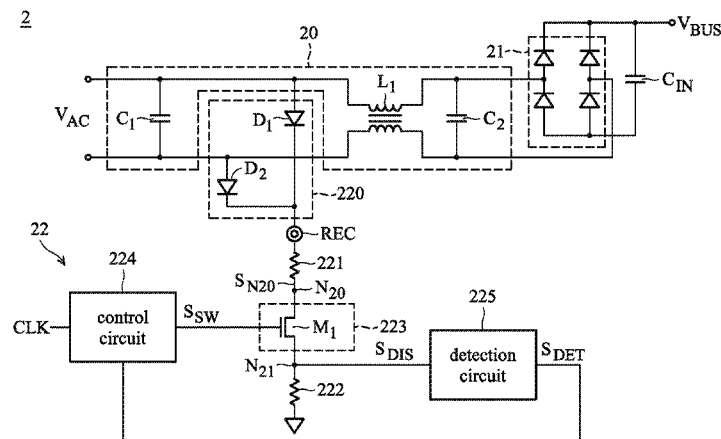
(52) **U.S. Cl.**
CPC **H02H 1/0007** (2013.01); **H02H 9/005** (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

(57) **ABSTRACT**

A discharge circuit for an electromagnetic interference (EMI) filter is provided. The discharge circuit includes a switch circuit, a control circuit, and a detection circuit. The switch circuit is coupled to an X-capacitor of the EMI filter. The control circuit is coupled to the switch circuit and configured to turn on the switch circuit in a predetermined period to provide a discharge path. The detection circuit is coupled to the discharge path. In the predetermined period, the detection circuit detects whether a cross point occurs between a discharge voltage signal on the discharge path and a reference voltage signal to generate a detection signal which is provided to the control circuit. When the detection circuit detects that the cross point does not occur, the control circuit continuously turns on the switch circuit according to the detection signal after the predetermined period has elapsed.

11 Claims, 8 Drawing Sheets



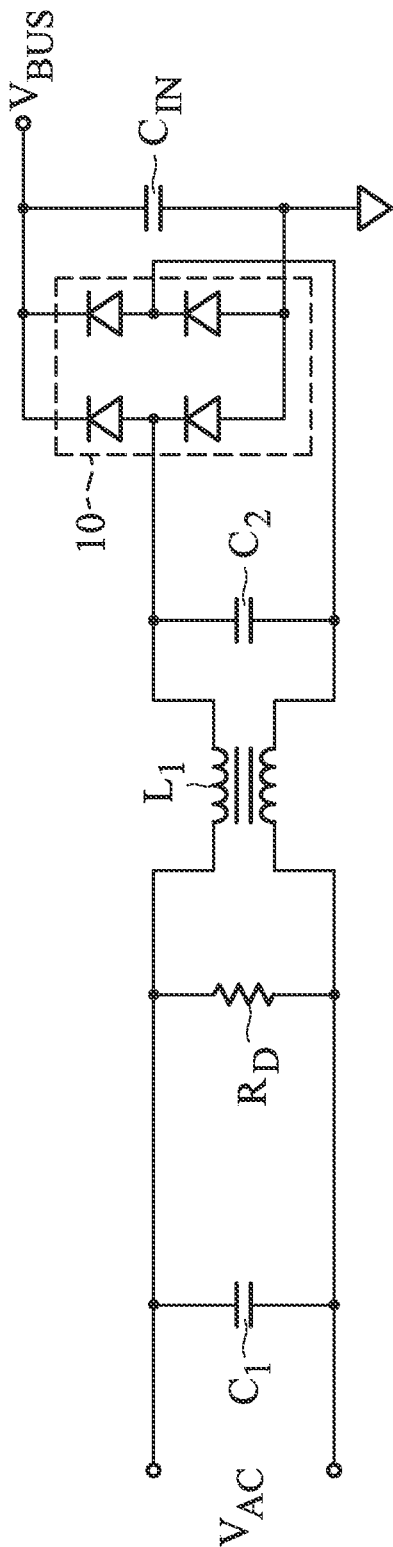
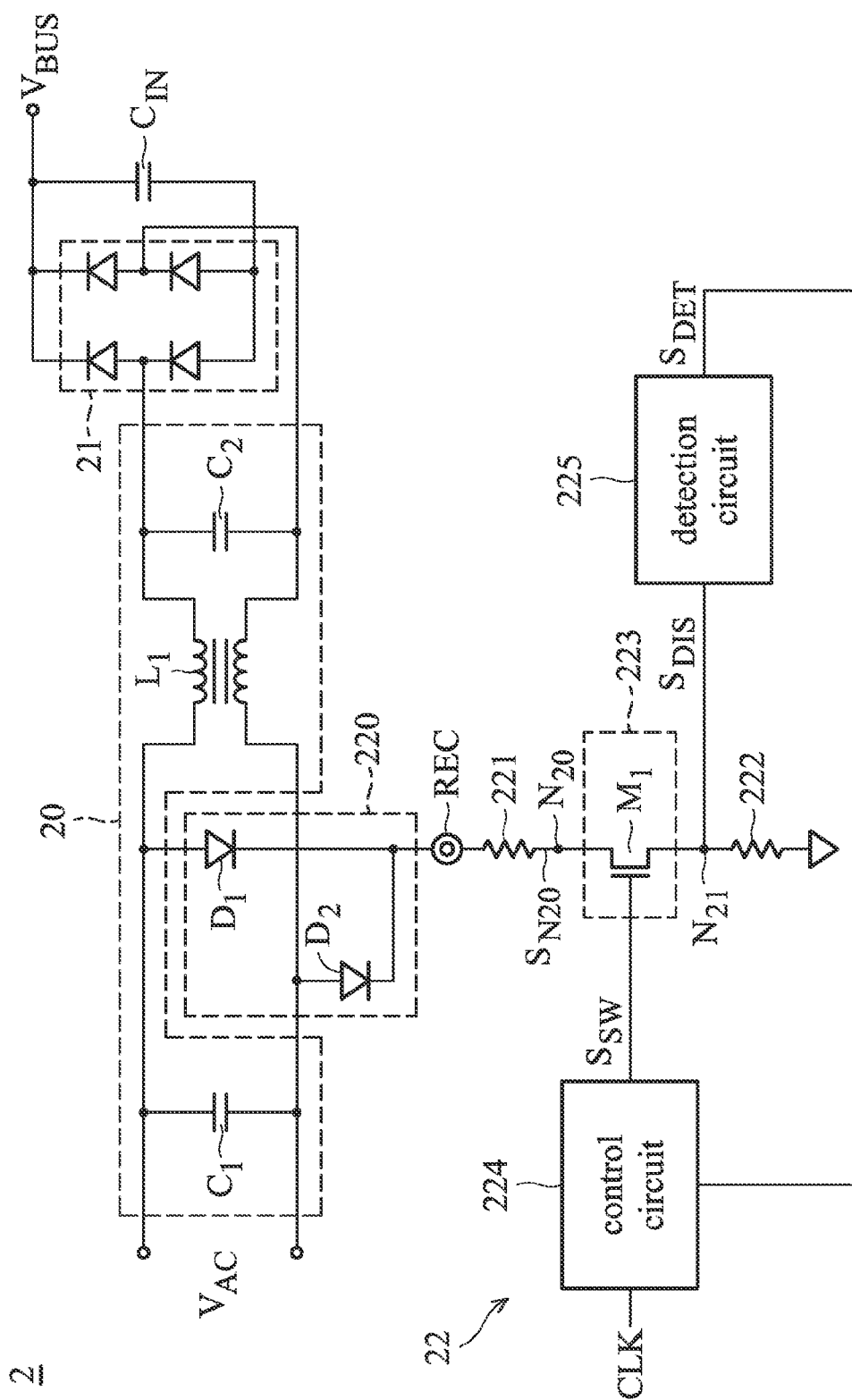


FIG. 1 (PRIOR ART)



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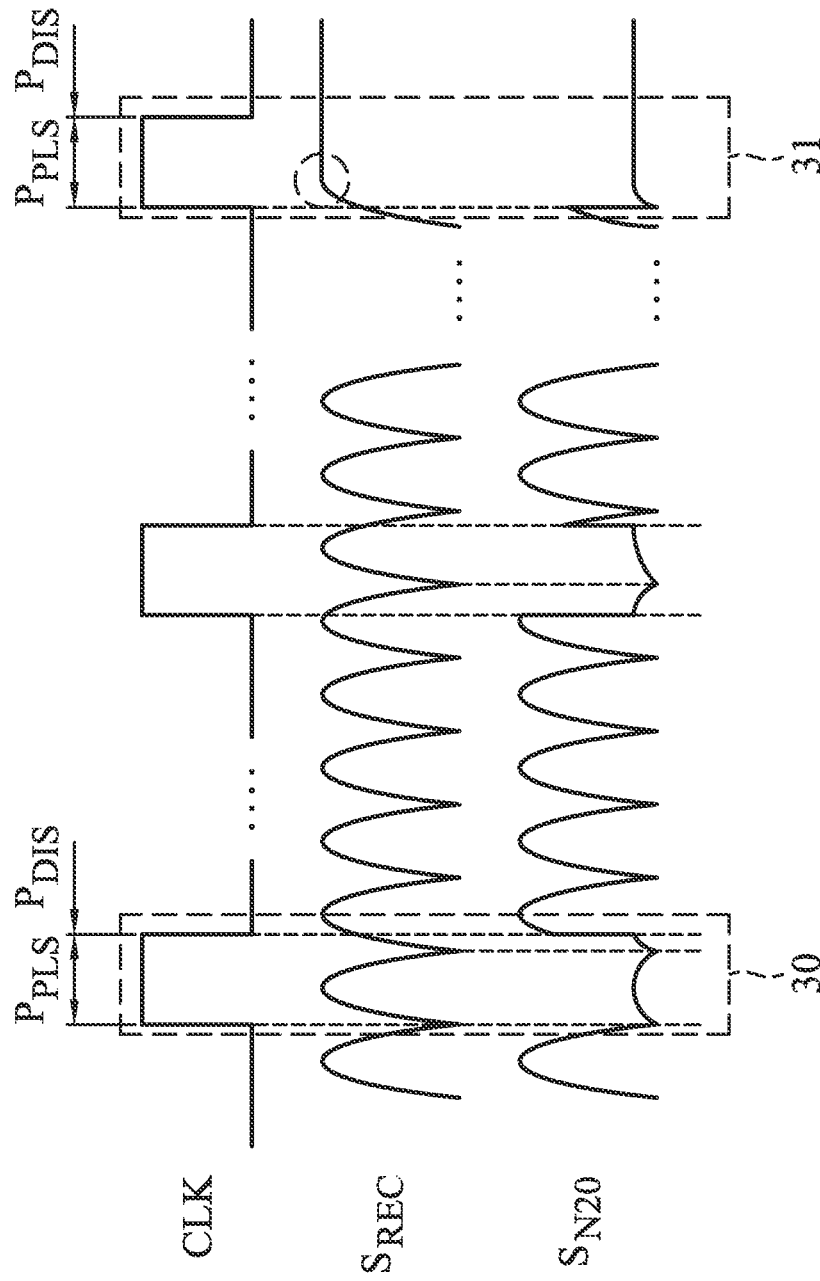


FIG. 3

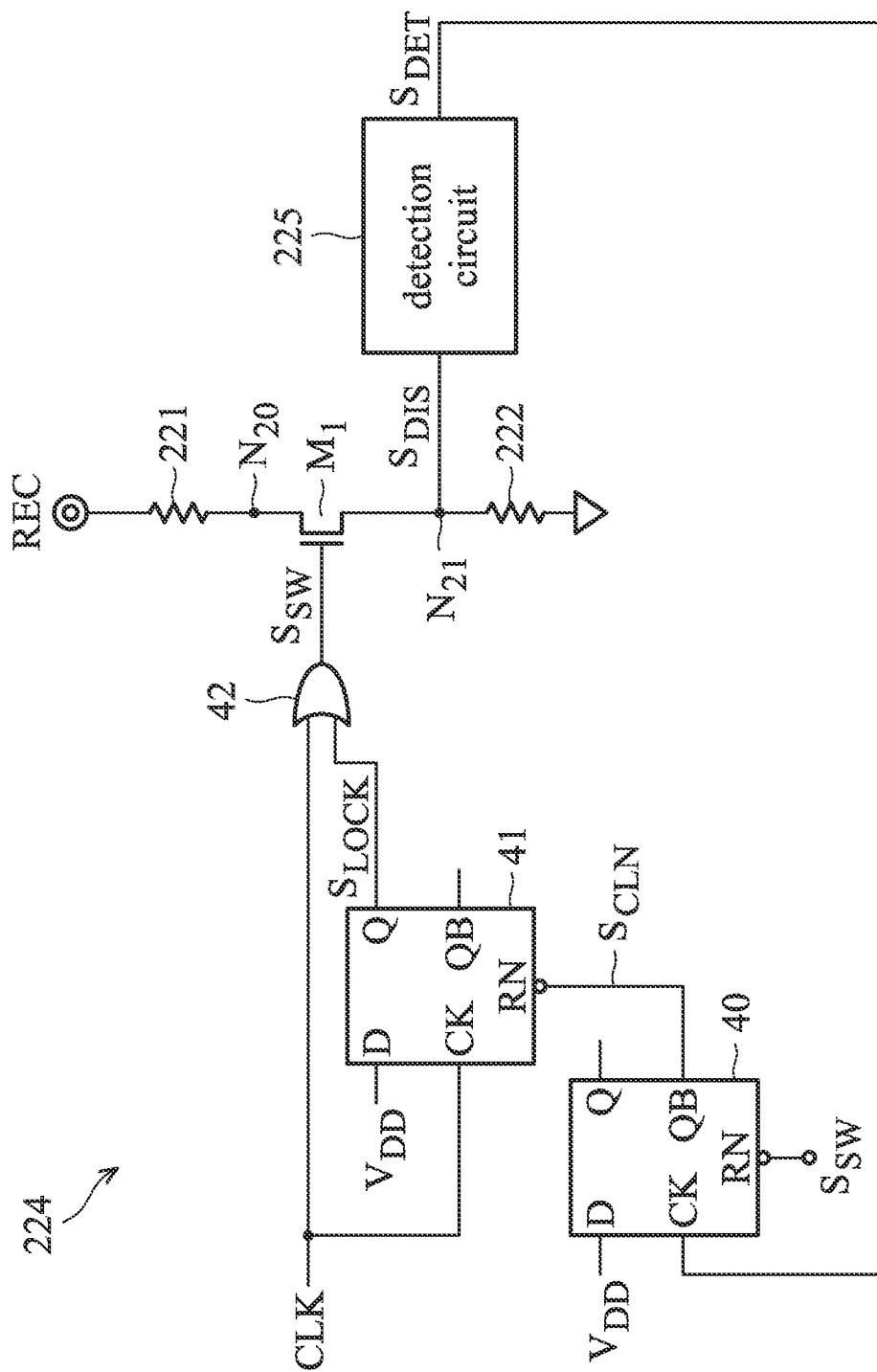


FIG. 4

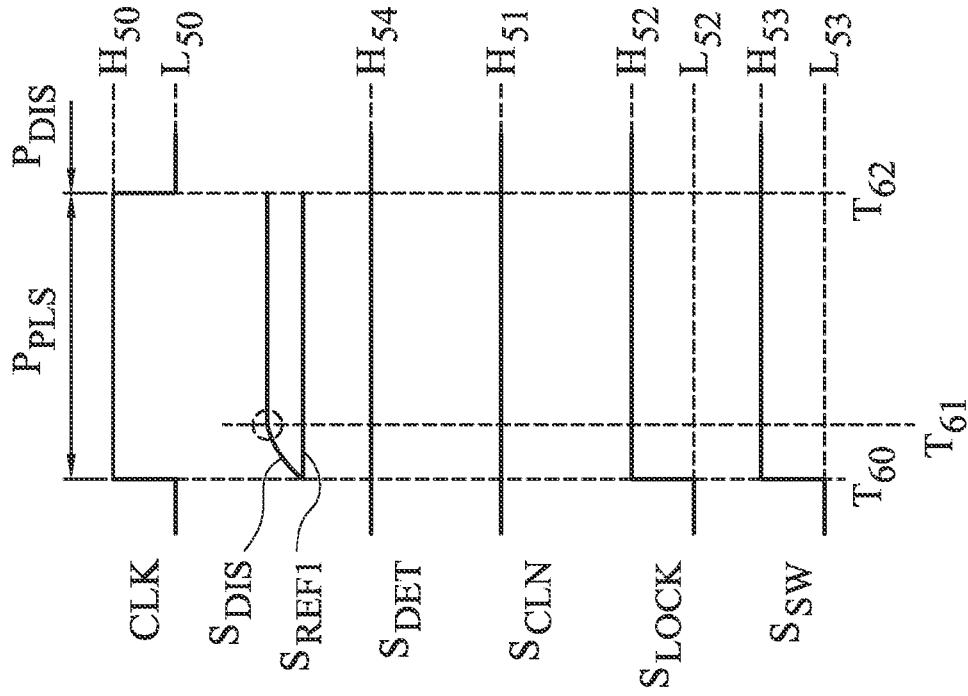


FIG. 5

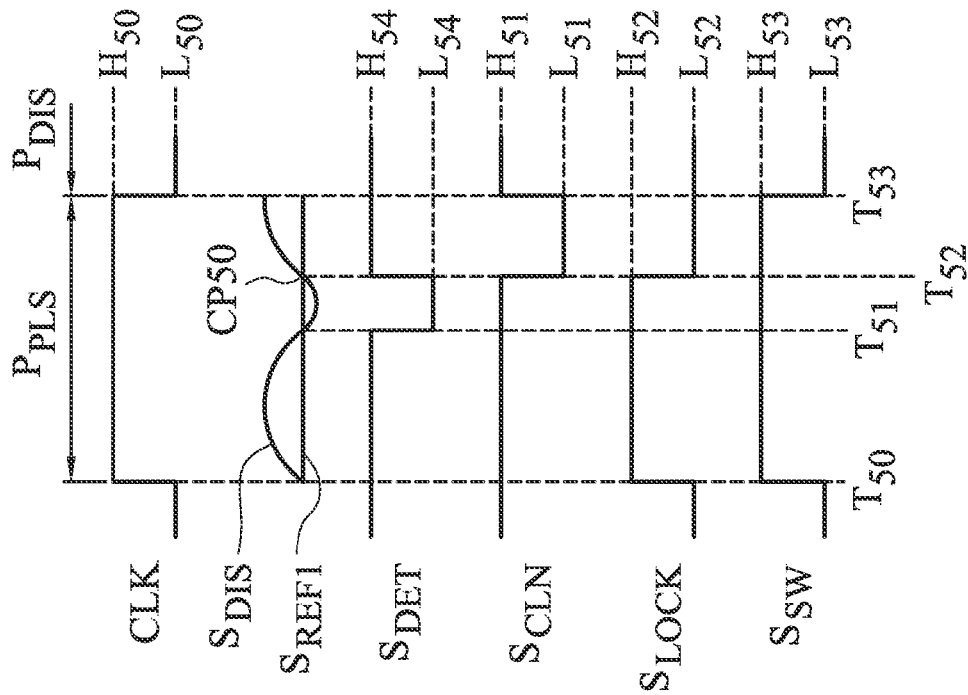


FIG. 6

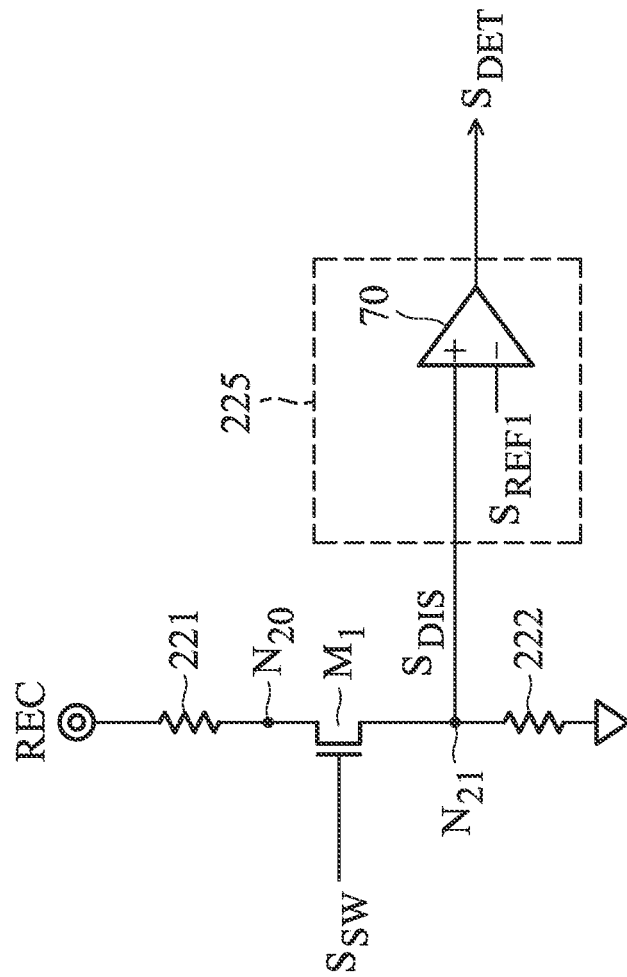
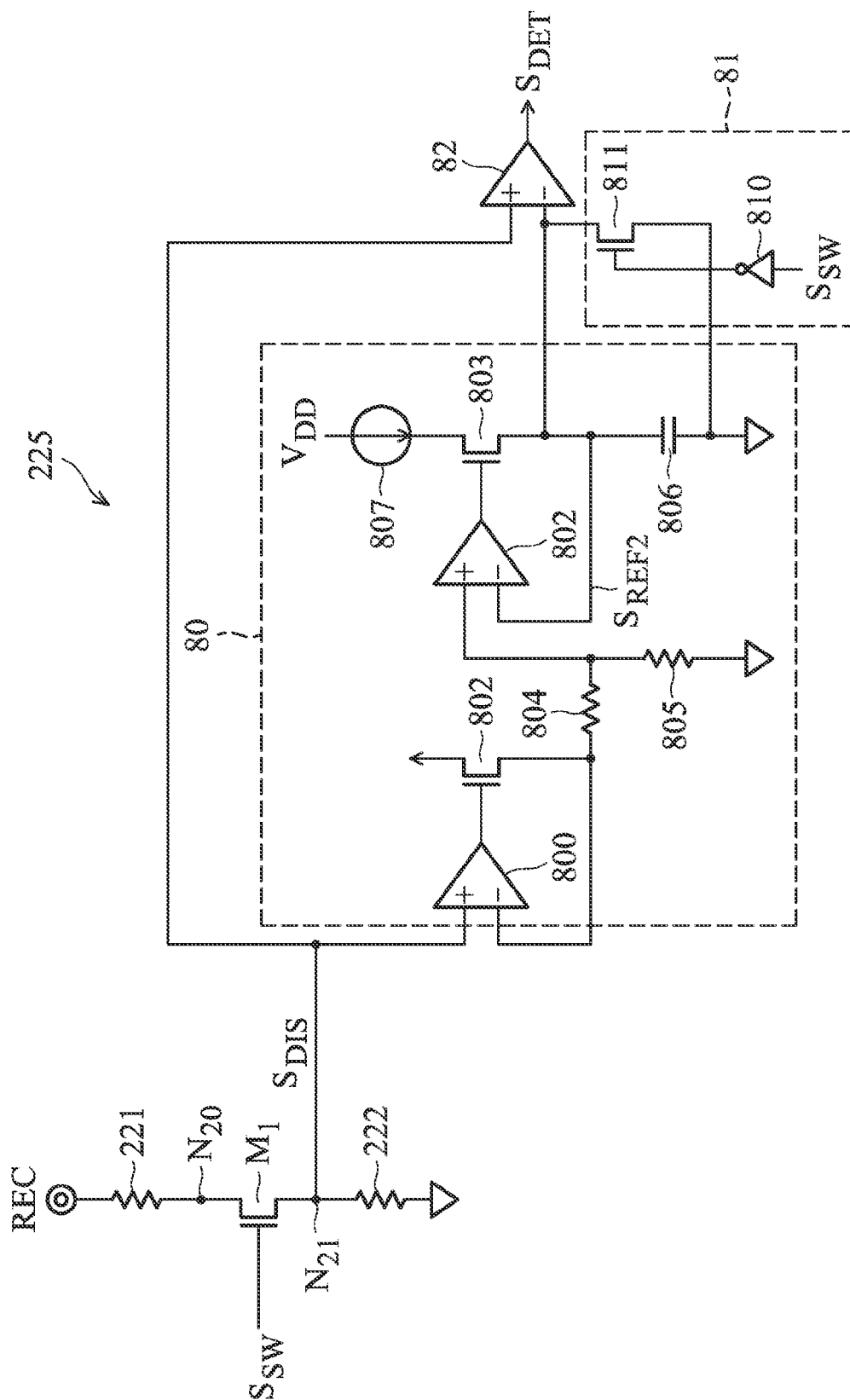


FIG. 7


$$\infty$$

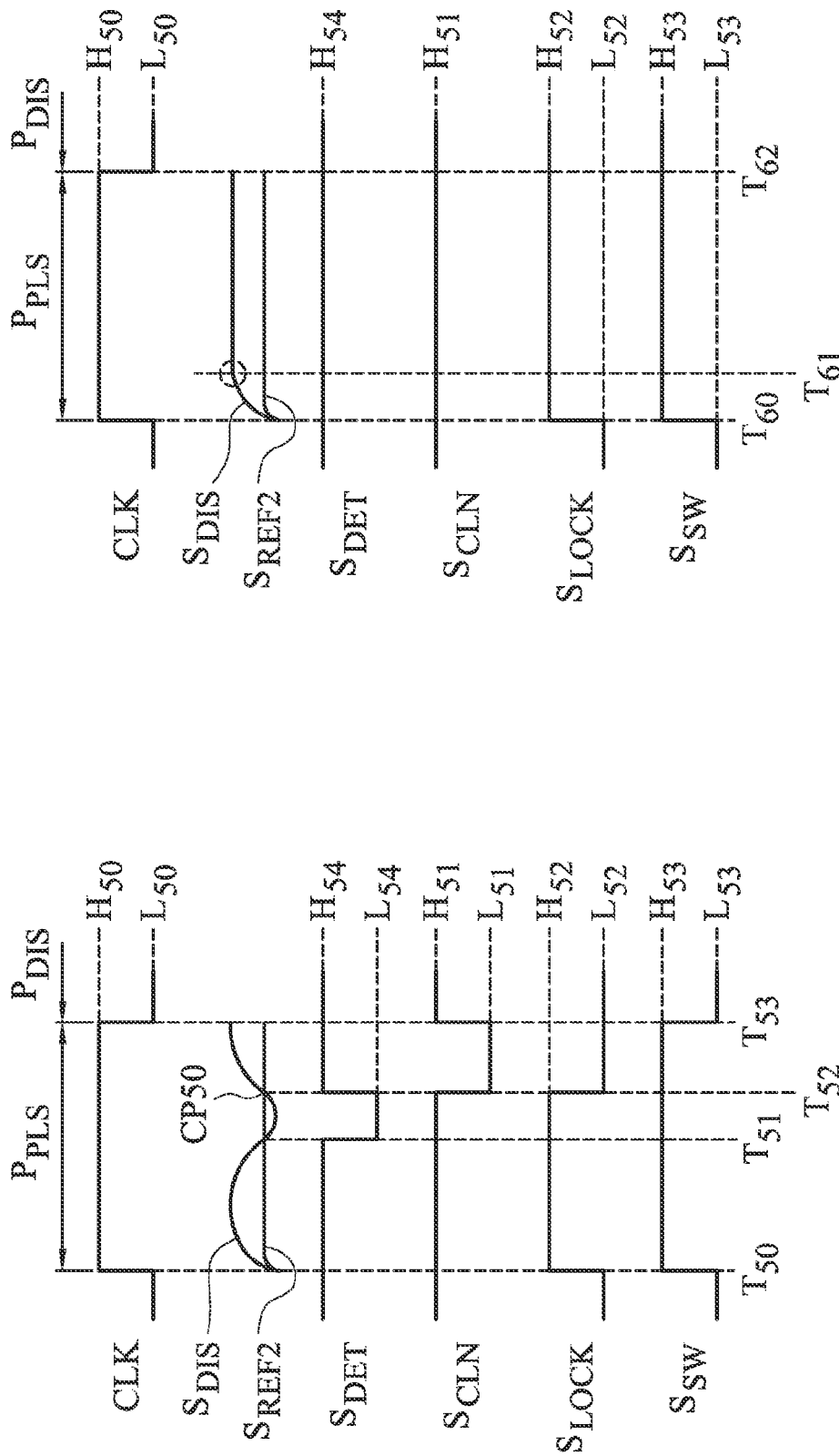


FIG. 9

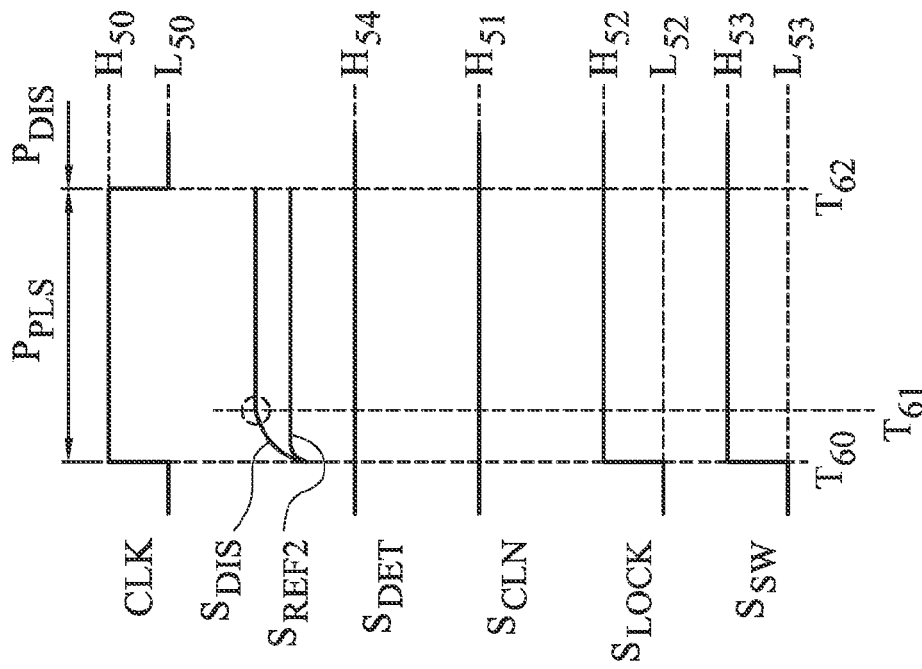


FIG. 10

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DISCHARGE CIRCUITS OF DISCHARGE PATHS FOR ELECTROMAGNETIC INTERFERENCE FILTERS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/909,408, filed on Nov. 27, 2013, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a discharge circuit for an electromagnetic interference (EMI) filter, and, more specifically, a discharge circuit for providing a discharge path for an X-capacitor of an EMI filter.

2. Description of the Related Art

Switching mode power supplies have been widely used to provide regulated power for computers, home appliances, communication equipments, etc. In recent years, the problem of power saving in switching mode power supplies has drawn much attention. Based on the restriction of environmental pollution, the computer and other equipment manufactures have been striving to meet the power management and energy conservation requirements.

FIG. 1 shows a traditional approach for filtering electromagnetic interference (EMI) and providing a DC voltage. An EMI filter located between a power source V_{AC} and a bridge rectifier 10 includes a choke L_1 , X-capacitors C_1 and C_2 . The X-capacitor C_1 is placed across the power source V_{AC} . The choke L_1 is coupled between the power source V_{AC} and the bridge rectifier 10. The X-capacitor C_2 is coupled between the choke L_1 and an input of the bridge rectifier 10. A bulk capacitor C_{IN} connected from an output of the bridge rectifier 10 to a ground is for stabilizing the DC voltage V_{BUS} at the output of the bridge rectifier 10. For satisfying regulations in US and European, a bleeding resistor R_D is generally placed across the X-capacitors C_1 or C_2 of the EMI filter. The bleeding resistor R_D will discharge the stored energy at the X-capacitors C_1 and C_2 to prevent an electric shock when end-user cut off the power source V_{AC} . In fact, the bleeding resistor R_D always has a fixed power-loss as long as the X-capacitors C_1 and C_2 have the stored voltage. Besides, for higher power source, the bleeding resistor R_D consumes much standby-power when the power supply is operated at no-load. Therefore, the disadvantage of the traditional approach causes a poor power saving at light-load and no-load. Because of the existence of the X-capacitors, it has become a major concern to reduce the standby-power.

BRIEF SUMMARY OF THE INVENTION

Thus, it is desirable to provide a discharge circuit for an electromagnetic interference (EMI) filter without a bleeding resistor, such that the power consumption can be saved, and the power management and energy conservation requirements can be met.

An embodiment of a discharge circuit for an electromagnetic interference (EMI) filter is provided. The discharge circuit comprises a switch circuit, a control circuit, and a detection circuit. The switch circuit is coupled to an X-capacitor of the EMI filter. The control circuit is coupled to the switch circuit and configured to turn on the switch circuit in a predetermined period to provide a discharge path. The detection circuit is coupled to the discharge path. In the predeter-

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mined period, the detection circuit detects whether a cross point occurs between a discharge voltage signal on the discharge path and a reference voltage signal to generate a detection signal which is provided to the control circuit. When the detection circuit detects that the cross point does not occur between the discharge voltage signal and the reference voltage signal, the control circuit continuously turns on the switch circuit according to the detection signal after the predetermined period has elapsed.

In an embodiment, the discharge circuit further comprises a first resistor and a second resistor. The first resistor is coupled between the X-capacitor and the switch circuit at a first node. The second resistor is coupled between the switch circuit and a reference ground at a second node. The discharge voltage signal is generated at the first node, and the detection circuit is coupled to the second node.

In another embodiment, the control circuit comprises a first D flip-flop, a second D flip-flop, and an OR gate. The first D flip-flop has an input terminal receiving a supply voltage, a clock terminal receiving the detection signal, a reset terminal receiving a switch signal, and an output terminal, and an inverted output terminal generates a clean signal. The second D flip-flop has an input terminal receiving the supply voltage, a clock terminal receiving a clock signal, a reset terminal receiving the clean signal, an output terminal generating a lock signal, and an inverted output terminal. The OR gate receives the clock signal and the lock signal and generates the switch signal according to the clock signal and the lock signal for turning on or off the switch circuit.

In an embodiment, the detection circuit comprises a comparator. The comparator compares the discharge voltage signal with the reference voltage signal to generate the detection signal. In another embodiment, the reference voltage signal varies with the discharge voltage signal before the predetermined period.

In further another embodiment, when the detection circuit detects that the cross point occurs between the discharge voltage signal on the discharge path and the reference voltage signal, the control circuit turns off the switch circuit according to the detection signal after the predetermined period.

Another exemplary embodiment of a discharge circuit for an electromagnetic interference (EMI) filter is provided. The discharge circuit comprises a control circuit and a detection circuit. The control circuit controls a discharge path to be formed from an X-capacitor of the EMI filter to a reference ground in a predetermined period. The detection circuit detects whether a cross point occurs between a discharge voltage signal on the discharge path and a reference voltage signal to generate a detection signal which is provided to the control circuit. When the detection circuit detects that the cross point occurs between the discharge voltage signal and the reference voltage signal, the control circuit cuts off the discharge path according to the detection signal after the predetermined period has elapsed. When the detection circuit detects that the cross point does not occur between the discharge voltage signal and the reference voltage signal, the control circuit conducts the discharge path according to the detection signal after the predetermined period.

A detailed description is given in the following embodiments with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

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FIG. 1 shows a traditional approach for filtering electro-magnetic interference (EMI) and providing a DC voltage;

FIG. 2 shows an exemplary embodiment of a power supply circuit according to the present invention;

FIG. 3 shows an exemplary embodiment of key signals of the power supply circuit in FIG. 2;

FIG. 4 shows an exemplary embodiment of a control circuit of the power supply circuit in FIG. 2;

FIG. 5 shows an exemplary embodiment of waveforms of key signals in the case where a discharge path is provided in a predetermined period and then cut off after the predetermined period has elapsed;

FIG. 6 shows an exemplary embodiment of waveforms of key signals in the case where a discharge path is provided in a predetermined period and after the predetermined period has elapsed;

FIG. 7 shows an exemplary embodiment of a detection circuit of the power supply circuit in FIG. 2;

FIG. 8 shows another exemplary embodiment of a detection circuit of the power supply circuit in FIG. 2;

FIG. 9 shows another exemplary embodiment of waveforms of key signals in the case where a discharge path is provided in a predetermined period and then cut off after the predetermined period has elapsed; and

FIG. 10 shows another exemplary embodiment of waveforms of key signals in the case where a discharge path is provided in a predetermined period and after the predetermined period has elapsed.

DETAILED DESCRIPTION OF THE INVENTION

The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

FIG. 2 shows an exemplary embodiment of a power supply circuit according to the present invention. As shown in FIG. 2, a power supply circuit 2 comprises an electromagnetic interference (EMI) filter 20, a bridge rectifier 21, a bulk capacitor C_{IN} , and a discharge circuit 22. The EMI filter 20 is coupled between a power source V_{AC} and a bridge rectifier 21. The EMI filter 20 comprises a choke L_1 , X-capacitors C_1 and C_2 . The X-capacitor C_1 is coupled across the power source V_{AC} . The choke L_1 is coupled between the power source V_{AC} and the bridge rectifier 21. The X-capacitor C_2 is coupled between the choke L_1 and an input of the bridge rectifier 21. A bulk capacitor C_{IN} is coupled from an output of the bridge rectifier 21 to a reference ground for stabilizing a DC voltage V_{BUS} at the output of the bridge rectifier 21, which serves as an output voltage of the power supply circuit 2. In the embodiment, there is no bleeding resistor coupled across the X-capacitors C_1 or C_2 of the EMI filter 20.

Referring to FIG. 2, the discharge circuit 22 is coupled to the X-capacitor C_1 of the EMI filter 20. The discharge circuit 22 comprises a rectifier 220, resistors 221 and 222, a switch circuit 223, a control circuit 224, and a detection circuit 225. In the embodiment, the switch circuit 223 is implemented by an N-type metal oxide semiconductor (NMOS) transistor M_1 which has a gate, a drain, and a source. The rectifier 220 is implemented by a full-wave rectifier to rectify the power source V_{AC} . The rectifier 220 comprises diodes D_1 and D_2 . Anodes of the diodes D_1 and D_2 are coupled to the power source V_{AC} . Cathodes of the diodes D_1 and D_2 are coupled to one terminal of the resistor 221 at a node REC. The other terminal of the resistor 221 is coupled to the drain of the

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NMOS transistor M_1 at a node N_{20} (the node N_{20} severing as one node of the resistor 221). The source of the NMOS transistor M_1 is coupled to one terminal of the resistor 222 at a node N_{21} (the node N_{21} severing as the other node of the resistor 221). The other terminal of the resistor 222 is coupled to the reference ground. The gate of the NMOS transistor M_1 receives a switch signal S_{SW} generated by the control circuit 224. The detection circuit 225 is coupled the node N_{21} where a discharge voltage signal S_{DIS} is generated to generate a detection signal S_{DET} . The control circuit 224 receives the detection signal S_{DET} and a clock signal CLK for generating the switch signal S_{SW} .

FIG. 3 shows an exemplary embodiment of key signals of the power supply circuit 2. The clock signal CLK is a periodical signal, and a period P_{PLS} when the pulse width of the clock signal CLK remains is defined as a predetermined period. S_{REC} represents a voltage signal which is generated by rectifying the power source V_{AC} through the rectifier 220. S_{N20} represents a voltage signal which is generated the node N_{20} between the resistor 221 and the NMOS transistor M_1 . In the embodiment, the predetermined period P_{PLS} is longer than the period of a half of the waveform of the voltage signal S_{REC} ; in other words, the predetermined period P_{PLS} is longer than the period of a half of the cycle of the power source V_{AC} . When the power source V_{AC} is being provided, in each predetermined period P_{PLS} , the control circuit 224 generates the switch signal S_{SW} according to the detection signal S_{DET} and the clock signal CLK to turn on the NMOS transistor M_1 . At this time, a discharge path from the X-capacitor C_1 to the reference ground through the resistor 221, the turned-on NMOS transistor M_1 , and the resistor 222 is provided. In the case where the power source V_{AC} is being provided, once the discharge path is provided due to the turned-on NMOS transistor M_1 (that in the predetermined period P_{PLS}), the magnitude of the voltage signal S_{N20} is reduced in response to the resistance of the resistor 222, and, however, the voltage signal S_{N20} varies with the waveform of the voltage signal S_{REC} . Moreover, since the NMOS transistor M_1 is turned on in the predetermined period P_{PLS} , the voltage signal S_{N20} is transmitted to the node N_{21} to serve as the discharge voltage signal S_{DIS} on the discharge path. In the predetermined period P_{PLS} , the detection circuit 225 detects whether a cross point occurs between the discharge voltage signal S_{DIS} and a reference voltage signal S_{REF1} to generate the detection signal S_{DET} . When the power source V_{AC} is being provided, the detection circuit 225 detects that cross point occurs between the discharge voltage signal S_{DIS} and the reference voltage signal S_{REF1} , and the control circuit 224 generates the switch signal S_{SW} according to the detection signal S_{DET} to turn off the NMOS transistor M_1 after the predetermined period P_{PLS} ; that is, in the period P_{DIS} following the predetermined period P_{PLS} , the control circuit 224 cuts off the discharge path according to the detection signal S_{DET} . When the power source V_{AC} stops being provided (such as when the plug of the power supply circuit 2 is out from the socket), the detection circuit 225 detects that no cross point occurs between the discharge voltage signal S_{DIS} and the reference voltage signal S_{REF1} in the predetermined period P_{PLS} , and the control circuit 224 generates the switch signal S_{SW} according to the detection signal S_{DET} to continuously turn on the NMOS transistor M_1 after the predetermined period P_{PLS} has elapsed; that is, in the period P_{DIS} following the predetermined period P_{PLS} , the control circuit 224 conducts the discharge path according to the detection signal S_{DET} .

FIG. 4 shows an exemplary embodiment of the control circuit 224. As shown in FIG. 4, the control circuit 224 comprises D flip-flops 40 and 41 and an OR gate 42. The D-flip-

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flop 40 has an input terminal D receiving a supply voltage V_{DD} , a clock terminal CK receiving the detection signal S_{DET} from the detection circuit 225, a reset terminal RN receiving the switch signal S_{SW} , an output terminal Q, and an inverted output terminal QB generating a clean signal S_{CLN} , wherein the clean signal S_{CLN} is inverse to a signal generated at the output terminal Q. The D flip-flop 41 has an input terminal D receiving the supply voltage V_{DD} , a clock terminal CK receiving the clock signal CLK, a reset terminal RN receiving the clean signal S_{CLN} , an output terminal Q generating a lock signal S_{LOCK} , and an inverted output terminal QB. The OR gate 42 receives the clock signal CLK and the lock signal S_{LOCK} and generates the switch signal S_{SW} according to the clock signal CLK and the lock signal S_{LOCK} . The switch signal S_{SW} is applied to turn on or off the NMOS transistor M_1 . In the embodiment, the D flip-flops 40 and 41 are triggered by rising edges of the signals at the respective clock terminals CK and reset by the signals with low levels at the respective reset terminals RN.

In FIG. 3, a dotted-line block 30 is taken an example for illustrating the case where the discharge path is provided in the predetermined period P_{PLS} and then cut off after the predetermined period P_{PLS} . The detailed waveforms of the key signals in the case of dotted-line block 30 are shown in FIG. 5. Before the time point T50, the detection signal S_{DET} is initially at a high level H54, the clean signal S_{CLN} is initially at a high level H51, and the lock signal S_{LOCK} is initially at a low level L52. At the time point T50 (the beginning of the predetermined period P_{PLS}), the clock signal CLK switches to a high level H50 from a low level L50. The switch signal S_{SW} switches to a high level H53 from a low level L53 in response to the switching of the clock signal CLK through the OR gate 42. In the period from the time point T50 to a time point T51, the discharge voltage signal S_{DIS} is larger than the reference voltage signal S_{REF1} , and the detection circuit 225 still generates the detection signal S_{DET} with the high level H54. Since the D flop-flop 40 is not triggered, the clean signal S_{CLN} remains at the high level H51. Moreover, at the time point T50, the lock signal S_{LOCK} switches to a high level H52 from the low level L52 in response to the rising edge of the clock signal CLK. Thus, the switch signal S_{SW} remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the lock signal S_{LOCK} with the high level H52 in the period from the time point T50 to the time point T51.

Then, in the period from the time point T51 to a time point T52, the discharge voltage signal S_{DIS} is less than the reference voltage signal S_{REF1} , and the detection circuit 225 generates the detection signal S_{DET} with a low level L54. The D flop-flop 40 is still not triggered, and the clean signal S_{CLN} remains at the high level H51 until the time point T52. Moreover, the D flop-flop 41 is also not triggered, and the lock signal S_{LOCK} remains at the high level H51 until the time point T52. Thus, the switch signal S_{SW} still remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the lock signal S_{LOCK} with the high level H52 in the period from the time point T51 to the time point T52.

In the period from the time point T52 to a time point T53, the discharge voltage signal S_{DIS} is larger than the reference voltage signal S_{REF1} again, and the detection circuit 225 generates the detection signal S_{DET} with the high level H54. Thus, a cross point CP50 occurs between the discharge voltage signal S_{DIS} and the reference voltage signal S_{REF1} in a rising direction, and, thus, the detection signal S_{DET} has a rising edge at the time point T52. The rising edge of the detection signal S_{DET} triggers the D flop-flop 40 to generate the clean

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signal S_{CLN} with a low level L51 at the time point T52, and the clean signal S_{CLN} remains at the low level L51 until the time point T53. The D flip-flop 41 is then reset by the clean signal S_{CLN} with the low level L51 to generate the lock signal S_{LOCK} with the low level L52. Thus, the switch signal S_{SW} still remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the lock signal S_{LOCK} with the low level L52 in the period from the time point T52 to the time point T53.

At the time point T53, the clock signal CLK switches to the low level L50 from the high level H50. Thus, the lock signal S_{LOCK} still remains at the low level L52. The switch signal S_{SW} switches to the low level L53 from the high level H53 according to the OR logic between the clock signal CLK with the low level L50 and the lock signal S_{LOCK} with the low level L52. The D flip-flop 40 is reset by the switch signal S_{SW} with the low level L53 to generate the clean signal S_{CLN} with the high level H51.

According to the above operation timing, in the predetermined period P_{PLS} , the switch signal S_{SW} with the high level H53 turns on the NMOS transistor M_1 , and the discharge path is provided for the X-capacitor C_1 . When the power source V_{AC} is being provided continuously which is realized by detecting that the cross point CP50 occurs in the predetermined period P_{PLS} , after the predetermined period P_{PLS} has elapsed (that is after the time point T53), the switch signal S_{SW} turns off the NMOS transistor M_1 , and the discharge path is cut off.

In FIG. 3, a dotted-line block 31 is taken an example for illustrating the case where the discharge path is provided in the predetermined period P_{PLS} and after the predetermined period P_{PLS} has elapsed. The detailed waveforms of the key signals in the case of dotted-line block 31 are shown in FIG. 6. Before the time point T60, the detection signal S_{DET} is initially at the high level H54, the clean signal S_{CLN} is initially at the high level H51, and the lock signal S_{LOCK} is initially at the low level L52. At the time point T60 (the beginning of the predetermined period P_{PLS}), the clock signal CLK switches to the high level H50 from the low level L50. The switch signal S_{SW} switches to the high level H53 from the low level L53 in response to the switching of the clock signal CLK through the OR gate 42. In the period from the time point T60 to a time point T61, the discharge voltage signal S_{DIS} is larger than the reference voltage signal S_{REF1} , and the detection circuit 225 still generates the detection signal S_{DET} with the high level H54. Since the D flop-flop 40 is not triggered, the clean signal S_{CLN} remains at the high level H51. Moreover, at the time point T60, the lock signal S_{LOCK} switches to the high level H52 from the low level L52 in response to the rising edge of the clock signal CLK. Thus, the switch signal S_{SW} remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the lock signal S_{LOCK} with the high level H52 in the period from the time point T60 to the time point T61.

Then, at the time point T61, the power source V_{AC} stops being provided, that is the plug of the power supply circuit 2 is out from the socket. At this time, the discharge signal S_{DIS} remains at an approximate DC level which is higher than the level of the reference voltage signal S_{REF1} . Thus, the discharge voltage signal S_{DIS} is larger than the reference voltage signal S_{REF1} , and the detection circuit 225 generates the detection signal S_{DET} with the high level H54. The clean signal S_{CLN} still remains at the high level H51, and lock signal S_{LOCK} remains at the high level H52. Thus, the switch signal S_{SW} remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the

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lock signal S_{LOCK} with the high level H52 in the period from the time point T61 to the time point T62.

At a time point T62, the clock signal CLK switches to the low level L50 from the high level H50. Since no cross point occurs between the discharge voltage signal S_{DIS} and the reference voltage signal S_{REF1} in the predetermined period P_{PLS} , the detection signal S_{DET} does not have any rising edge. The D flip-flop 40 thus still generates the clean signal S_{CLN} with the high level H51. The D flip-flop 41 does not reset by the clean signal S_{CLN} . Thus, the lock signal S_{LOCK} still remains at the high level H52. The switch signal S_{SW} still remains at the high level H53 according to the OR logic between the clock signal CLK with the high level H50 and the lock signal S_{LOCK} with the high level H52 from the time point T62.

According to the above operation timing, in the predetermined period P_{PLS} , the switch signal S_{SW} with the high level H53 turns on the NMOS transistor M_1 , and the discharge path is provided for the X-capacitor C_1 . When the power source V_{AC} stops being provided (that is the plug of the power supply circuit 2 is out from the socket), after the predetermined period P_{PLS} (that is after the time point T53), the switch signal S_{SW} still remains at the high level H53 to turn on the NMOS transistor M_1 , and the discharge path is provided continuously.

In the embodiment of FIGS. 5 and 6, the reference voltage signal S_{REF1} is predetermined to be at an approximate DC level. FIG. 7 shows an exemplary embodiment of the detection circuit 225. In order to illustrate clearly, FIG. 7 also shows the resistors 221 and 222 and the NMOS transistor M_1 . As shown in FIG. 7, the detection circuit 225 comprises a comparator 70. A positive input terminal of the comparator 70 is coupled to the node N21 to receive the discharge voltage signal S_{DIS} , and a negative input terminal thereof receives the reference voltage signal S_{REF1} with the approximate DC level. By comparing the discharge voltage signal S_{DIS} with the reference voltage signal S_{REF1} , the detection signal S_{DET} is generated at an output terminal of the comparator 70. Through the comparison operation of the comparator 70, whether a cross point occurs between the discharge voltage signal S_{DIS} with the reference voltage signal S_{REF1} is detected.

In another embodiment, the reference voltage signal S_{REF2} is determined by the magnitude of the discharge voltage signal S_{DIS} occurring before the predetermined period P_{PLS} , particularly, by the magnitude of the discharge voltage signal S_{DIS} occurring the period P_{DIS} (shown in FIG. 3) before the current predetermined period P_{PLS} . FIG. 8 shows another exemplary embodiment of the detection circuit 225. In order to illustrate clearly, FIG. 8 also shows the resistors 221 and 222 and the NMOS transistor M_1 . As shown in FIG. 8, the detection circuit 225 comprises a buffer 80, a reset circuit 81, and a comparator 82. The buffer 80 comprises operational amplifiers 800 and 801, NMOS transistors 802 and 803, resistors 804 and 805, a capacitor 806, and a current source 807. Through the operation of the buffer 80, a voltage which is determined by the magnitude of the discharge voltage signal S_{DIS} occurring the previous period P_{DIS} is stored in the capacitor 806. The voltage stored in the capacitor 806 serves as the reference voltage signal S_{REF2} in the current predetermined period P_{PLS} . Due to the capacitor 806 and the current source 807, the level of the reference voltage signal S_{REF2} gradually rises and then remains at an approximate DC level. Thus, in the embodiment, the reference voltage signal S_{REF2} varies with the magnitude of the discharge voltage signal S_{DIS} occurring the previous the period P_{DIS} . The reset circuit 81 is coupled to the capacitor 806 and comprises an inverter 810

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and an NMOS transistor 811. The inverter 810 receives the switch signal S_{SW} and inverts the switch signal S_{SW} to control the NMOS transistor 811. Through the operations of the inverter 810 and the NMOS transistor 811, after the predetermined period P_{PLS} (that the current period P_{DIS}), the level of the reference voltage S_{REF2} is reset to a level of the reference ground by discharging the capacitor 806. Then, the level of the reference voltage S_{REF2} will be re-determined for the next predetermined period P_{PLS} . A positive input terminal of the comparator 82 is coupled to the node N21 to receive the discharge voltage signal S_{DIS} , and a negative input terminal thereof receives the reference voltage signal S_{REF2} with the approximate DC level. By comparing the discharge voltage signal S_{DIS} with the reference voltage signal S_{REF2} , the detection signal S_{DET} is generated at an output terminal of the comparator 82. Through the comparison operation of the comparator 82, whether a cross point occurs between the discharge voltage signal S_{DIS} and the reference voltage signal S_{REF2} is detected. The reference voltage signal S_{REF2} used by the detection circuit 225 of FIG. 8 is shown in FIGS. 9 and 10 which correspond the cases of the FIGS. 5 and 6.

While the invention has been described by way of example and in terms of the preferred embodiments, it is to be understood that the invention is not limited to the disclosed embodiments. On the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A discharge circuit for an electromagnetic interference (EMI) filter, comprising:

a switch circuit coupled to an X-capacitor of the EMI filter; a control circuit, coupled to the switch circuit, for turning on the switch circuit in a predetermined period to provide a discharge path; and a detection circuit, coupled to the discharge path, for, in the predetermined period, detecting whether a cross point occurs between a discharge voltage signal on the discharge path and a reference voltage signal to generate a detection signal which is provided to the control circuit, wherein when the detection circuit detects that the cross point does not occur between the discharge voltage signal and the reference voltage signal, the control circuit continuously turns on the switch circuit according to the detection signal after the predetermined period has elapsed.

2. The discharge circuit as claimed in claim 1 further comprising:

a first resistor coupled between the X-capacitor and a first node of the switch circuit; a second resistor coupled between a second node of the switch circuit and a reference ground, wherein the discharge voltage signal is generated at the second node, and the detection circuit is coupled to the second node.

3. The discharge circuit as claimed in claim 1, wherein the control circuit comprises:

a first D flip-flop having an input terminal receiving a supply voltage, a clock switch signal, an output terminal, and an inverted output terminal generates a clean signal; a second D flip-flop having an input terminal receiving the supply voltage, a clock terminal receiving a clock signal, a reset terminal receiving the clean signal, an output terminal generating a lock signal, and an inverted output terminal; and

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an OR gate receiving the clock signal and the lock signal and generating the switch signal according to the clock signal and the lock signal for turning on or off the switch circuit.

4. The discharge circuit as claimed in claim 1, wherein the detection circuit comprises:

a comparator for comparing the discharge voltage signal with the reference voltage signal to generate the detection signal.

5. The discharge circuit as claimed in claim 4, wherein the reference voltage signal varies with the discharge voltage signal before the predetermined period.

6. The discharge circuit as claimed in claim 1, wherein when the detection circuit detects that the cross point occurs between the discharge voltage signal and the reference voltage signal, the control circuit turns off the switch circuit after the predetermined period has elapsed.

7. A discharge circuit for an electromagnetic interference (EMI) filter, comprising:

a control circuit controlling a discharge path to be formed from an X-capacitor of the EMI filter to a reference ground in a predetermined period; and

a detection circuit for detecting whether a cross point occurs between a discharge voltage signal on the discharge path and a reference voltage signal to generate a detection signal which is provided to the control circuit, wherein when the detection circuit detects that the cross point occurs between the discharge voltage signal and the reference voltage signal, the control circuit cuts off the discharge path according to the detection signal after the predetermined period has elapsed; and

wherein when the detection circuit detects that the cross point does not occur between the discharge voltage signal and the reference voltage signal, the control circuit

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conducts the discharge path according to the detection signal after the predetermined period has elapsed.

8. The discharge circuit as claimed in claim 7 further comprising:

a first resistor coupled between the X-capacitor and a first node;

a second resistor coupled between the first node and the reference ground, wherein the discharge voltage signal is generated at the first node.

9. The discharge circuit as claimed in claim 7, wherein the control circuit comprises:

a first D flip-flop having an input terminal receiving a supply voltage, a clock terminal receiving the detection signal, a reset terminal receiving a switch signal, an output terminal, and an inverted output terminal generating a clean signal;

a second D flip-flop having an input terminal receiving the supply voltage, a clock terminal receiving a clock signal, a reset terminal receiving the clean signal, an output terminal generating a lock signal, and an inverted output terminal; and

an OR gate receiving the clock signal and the lock signal and generating the switch signal according to the clock signal and the lock signal for conducting or cutting off the discharge path.

10. The discharge circuit as claimed in claim 7, wherein the detection circuit comprises:

a comparator for comparing the discharge voltage signal with the reference voltage signal to generate the detection signal.

11. The discharge circuit as claimed in claim 10, wherein the reference voltage signal varies with the discharge voltage signal before the predetermined period.

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